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Modelling Forest Harvesting Effects on Maximum Daily Peak Flow at Upper Penticton Creek

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Introduction

Forest harvesting can have a significant effect on hydrologic processes such as interception, snowmelt, and evaporation, as well as on the magnitude and frequency of geomorphically and ecologically important streamflow events. These changes may affect water supplies, channel form, and the functioning of stream/riparian ecosystems. This note describes preliminary research modelling the effects of forest cover removal on peak flows in a small headwater stream in the south-central Okanagan.

Study Area

This study modelled streamflow in 241 Creek, a small headwater stream northeast of Penticton, B.C. (Figure 1). The 241 Creek watershed covers a gently sloping area of 4.8 km², and an elevation range of 1600–2025 m, and has a southerly orientation. The area is in the dry Engelmann Spruce–Subalpine Fir Zone and is forested with lodgepole pine (*Pinus contorta* Dougl.) and some Engelmann spruce and subalpine fir (*Picea engelmannii* Parry and *Abies lasiocarpa* (Hook.) Nutt). Stands are evenly spaced, reach a maximum height of 25 m, and have a canopy density of 35–50%. Soils are coarse sandy-loam over loamy sand, high in coarse fragments, and well or rapidly drained. The mean annual precipitation at

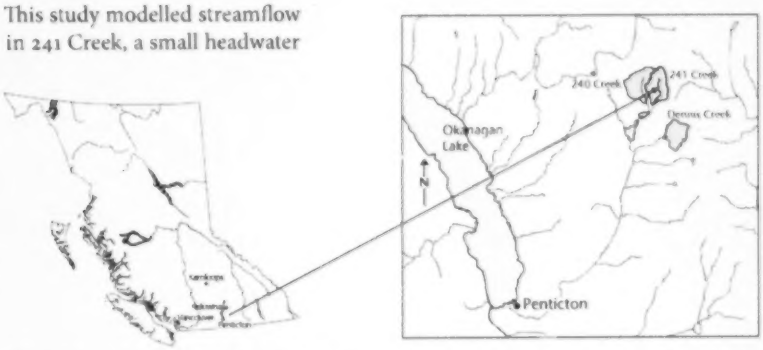

FIGURE 1 *Location of the Upper Penticton Creek watershed experiment and the 241 Creek study watershed.*

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Upper Penticton Creek is 750 mm, with approximately half falling as snow. Air temperatures range from -20°C in winter to 20°C in summer. Streamflow varies from 1.5 $m^3 s^{-1}$ in May to 0.01 $m^3 s^{-1}$ during the August through April low-flow period.

Methods

Streamflow in 241 Creek was simulated for a variety of hypothetical clearcut harvesting scenarios using the distributed hydrology-soil-vegetation model (DHSVM) developed at the University of Washington (Wigmosta et al. 1994) and calibrated for the watershed by Thyer et al. (2004). Within DHSVM, precipitation inputs are routed via a grid system through the watershed to the stream network. Digital elevation data are used to model topographic controls on meteorology, energy, and water movement. Water balance equations, which account for evaporation, snow accumulation and melt, and soil moisture storage, are solved for every grid cell in the model domain at hourly time steps. Grid cells exchange water with adjacent cells, resulting in a downslope distribution of surface and subsurface water across the watershed. This surface and subsurface runoff is eventually collected in the channel network and routed to the basin outlet as streamflow.

When compared to field measurements, the DHSVM successfully simulated the 241 Creek hydrograph, forest and clearcut snow accumulation and melt rates, rainfall interception, tree transpiration, and differences in soil moisture between a dry and wet summer (Thyer et al. 2004). These tests of internal processes provide confidence in the DHSVM's ability to reliably assess the effects of forest harvesting on streamflow.

A hypothetical 100-year weather record, based on the statistical distribution of the 10-year record at Upper Penticton Creek, was generated following Schnorbus and Alila (2004a). These weather data were used in all harvest and control scenario simulations. In the simulations, clearcuts were distributed either above or below the H50 (median) elevation. Harvest areas ranged from 10 to 50% of watershed area in increments of 10%. A scenario testing the harvesting of 100% of the basin area was also simulated. Roads were not included in these scenarios in order to determine the effects of forest cover removal alone. The effects of roads are still being investigated.

Peak flows were simulated for each year under each harvest scenario. These data were then used to estimate peak flow magnitude for various return periods (Tr). Relative changes in peak flows were determined by comparing the simulated post-harvest peak flow to that simulated for the control version of the same watershed (i.e., completely intact forest cover). Clearcuts were assumed to remain as clearcut throughout each simulation so that the results would represent the peak flow change in the first few critical years following harvesting.

Results and Discussion

Figure 2 shows the simulated changes in daily peak streamflow with increasing harvest area. Statistically significant increases in peak flow magnitude for Tr = 2, 10, and 50 years are predicted after 40%, 30%, and 20% of the watershed area has been harvested, respectively. The hydrologic or ecological importance of the simulated changes in flow will depend on stream channel morphology.

The relative change in peak flow, or peak flow response, shows some sensitivity to the elevation of the harvest treatment (i.e., above or below H50); however, the differences were less than 5% and are considered to be within measurement and modelling uncertainty. Consequently, Figure 2 presents the results of clearcutting above the H50 elevation.

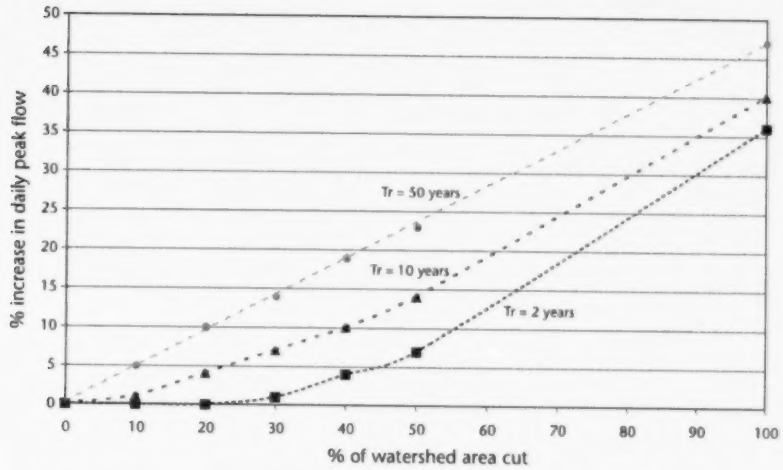

FIGURE 2 *Maximum changes in 2-, 10-, and 50-year return period daily peak flows with increasing clearcut area in the 241 Creek watershed, estimated using DHSVM.*

The larger, less frequent events consistently show a greater response than the smaller, more frequent events. When 100% of the watershed area is clearcut, the maximum predicted response in peak flow is 36%, 40%, and 47% for Tr = 2, 10, and 50 years, respectively. At 30% harvest, peak flow changes of 1%, 7%, and 15% are expected for Tr = 2, 10, and 50 years, respectively. At 20% harvest, peak flows are predicted to change by less than 10%, a result that is consistent with field observations.

Conclusions

Evidence from snow-dominated watersheds in the southern interior of British Columbia indicates that streamflow-generating processes can be altered as a result of logging (Cheng 1989; Winkler et al. 2003). This study supports the view that forest harvesting increases peak flows in snow-dominated watersheds in the southern interior of British Columbia, and shows that the magnitude of those increases is greater for larger return period flows. However, the results also show that in watersheds similar to those studied at Upper Penticton Creek the predicted increases in peak flow are less than 50% regardless of the extent of forest cover removal.

The results of this study reflect the subdued topography and small size of the 241 Creek watershed; therefore, the results should be extrapolated with caution and only to watersheds with similar morphology. An investigation in the West Kootenays indicates that watersheds with larger-elevation gradients or of a larger size than the 241 Creek watershed can be expected to display greater sensitivity to harvest elevation. The presence of a large, subalpine area can also substantially mitigate peak flow changes (Schnorbus and Alila 2004b).

Numerical modelling work is continuing at Upper Penticton Creek, as is research investigating watershed response to increasing rates of cut and the effects of increases in peak flows on water quality, stream channels, and aquatic habitat. The results of both the field experimentation and numerical modelling will advance our understanding of hydrologic processes, helping to improve water resource management.

References

Cheng, J.D. 1989. Streamflow changes after clearcut logging of a pine beetle-infested watershed in southern British Columbia, Canada. Water Resources Research 47(6):1063–7.

Church, M. 2002. Geomorphic thresholds in riverine landscapes. Freshwater Biology 74:541–7.

Schnorbus, M.A., and Y. Alila. 2004a. Generation of an hourly meteorological time series for a mountainous basin in British Columbia for use in numerical hydrologic modeling. Journal of Hydrometeorology, under review.

Schnorbus, M.A., and Y. Alila. 2004b. Forest harvesting impacts on the peak flow regime in the Columbia Mountains of southeastern British Columbia: an investigation using long-term numerical modelling. Water Resources Research, doi: 10.1029/2003WR002918, in print.

Thyer, M., J. Beckers, D.L. Spittlehouse, Y. Alila, and R.D. Winkler. 2004. Diagnosing a distributed hydrologic model for two high elevation forested catchments based on detailed stand and basin scale data. Water Resources Research 40: W01103, doi:10.1029/2003WR002414.

Wigmosta, M.S., L.W. Vail, and D.P. Lettenmaier. 1994. A distributed hydrology-vegetation model for complex terrain. Water Resources Research 30(6):1665–79.

Winkler, R.D., D.L. Spittlehouse, B.A. Heise, T.R. Giles, and Y. Alila. 2003. The Upper Penticton Creek watershed experiment: a review at year 20. *In* Water stewardship: how are we managing? Proceedings 56th Canadian Water Resources Association Conference, pp. 51–8.

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